Memorandum

MIAMI-DADE COUNTY

Date: May 16, 2006

INLUC
Agenda Item No. 7(J)

To: Honorable Chairman Joe A. Martinez
and Members, Board of County Commissioners

From: George M. Burgess
County Manager

Subject: Alternate Power Sources for Traffic Signals and Street Lights

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At the September 15, 2005, Regional Transportation Committee (RTC) meeting, Commissioner Souto requested that staff explore the use of alternative power sources for traffic signals, street lights, and other County infrastructure to enable service to be continuously provided to the public during power outages. To that effect, the Public Works Department (PWD) has provided the following information.

The most promising and realistic solution to this serious problem is to require Florida Power & Light (FPL) to strengthen and/or relocate its existing infrastructure so that this infrastructure will not be susceptible to damage by windstorms. Improving the reliability of the existing power supply system is the best solution to the community's emergency power

Nonetheless, a wide number of alternative power supply solutions may be considered. In arguable order of most-to-least promising, they are as follows:

1. **Temporary propane generators** were used successfully at approximately 50 signalizations in Miami-Dade County (MDC) by a contractor working for the Florida Department of Transportation (FDOT) and by the Hialeah Police Department in the aftermath of Hurricane Wilma. They were popular with the public and there was a demand for more of them. While a number of problems with this technology became apparent, none are insurmountable:

    a. They are susceptible to theft.

    b. They must be refueled regularly, typically daily, depending on the tank size and power draw, to prevent them from running out of fuel.

    c. Qualified electricians must install them. Such personnel are difficult to find after a hurricane. County and private-sector electricians are almost always very busy with other recovery efforts.

    d. Deploying, maintaining, removing, and storing hundreds of emergency generators to serve all major signalizations in MDC would be a monumental undertaking.

Nonetheless, this could be a viable solution for use after future emergencies. In order for this plan to be implemented and not detract from the need for Public Works Signal Technicians to work full time after hurricanes to carry out permanent signal repair efforts, Public Works could identify, train, and place under contract a number of qualified private-sector electricians in advance of the next hurricane season. In an emergency, they could then be expected to deploy and service any generators that are procured through the County or the State.

2. **Battery-based Uninterruptible Power Supply systems (UPS's)** can be permanently installed in a cabinet adjacent to the traffic signal control-cabinet. The batteries are charged by the commercial power supply. When that supply is interrupted, the batteries automatically begin powering the traffic signal. During the past year, the City of Key West completed the installation of these UPS units at 17 signalized intersections via a project that was funded by FDOT. The units worked well during and immediately after power outages caused by the four (4) tropical storms that passed through or near the Keys this past season. While a number of problems with this technology became apparent, none are insurmountable:

a. The cost to furnish and install a UPS system that provides 80 hours of back-up power is approximately $25,000 per intersection (assuming a quantity discount and completion of the upcoming LED conversion project). The price could vary if more or fewer hours of back-up power are sought. Therefore, installing a UPS system at the 100 most major signals of Miami-Dade's 2630 signalizations would cost approximately $2.5 Million.

b. Annual maintenance costs are estimated at $700 per intersection. Therefore, installing a UPS system at our 100 most major signals would cost approximately $70,000 to maintain annually.

c. The backup service would only last approximately 80 hours -- very beneficial for short and medium duration outages, but almost inconsequential for extremely long power outages. The company that installed the UPS's in Key West is preparing a proposal that would accommodate the periodic recharging of the batteries by portable generators during longer-term outages, but such would further increase the already high cost of this solution.

Nonetheless, this is a viable solution that could be considered for use in about one year, after the County's incandescent traffic signal bulbs are replaced with LED modules. FDOT is willing to fund a project of this type if a currently funded project of comparable cost can be identified and sacrificed or postponed.

3. **Temporary solar panels**, capable of powering a temporary traffic signal, were recently utilized by the City of Coral Springs Police Department and found to be successful. However, the typical intersection widths and traffic volumes are less in Coral Springs than in Miami-Dade County. Nonetheless, the technology is apparently much improved over that which was tested by Miami-Dade Public Works in the aftermath of Hurricane Andrew. However, a number of problems became apparent, some of which may be difficult or impossible to overcome:

a. The devices stand relatively unprotected in the center of the intersection and occasionally get hit and destroyed by left-turning drivers.

b. Drivers in the right-most approach lane(s) occasionally do not see the single head in the center of the intersection and become involved in right-angle crashes.

c. The initial cost is about $11,000 per intersection.

d. Deploying, maintaining, removing and storing hundreds of portable solar-powered traffic signalizations would be a monumental undertaking.

Nonetheless, this is a viable solution that could be considered for use by the County and local police departments at minor intersections after future emergencies.

4. **Permanent solar panels** capable of driving small power-consuming devices such as flashing signs and bus shelters are currently on the market from several manufacturers. To date, no one has successfully expanded the use of this technology to the capacity required to power a full traffic signalization or even a street light with any degree of reliability. Two (2) entities are working on such a design. Most promising, the Florida Solar Energy Center has volunteered to design a system that will power a typical signalization using permanently mounted solar panels. They plan to present their design to Public Works in late March 2006. Public Works staff looks forward to evaluating the design and will provide a follow-up report to the Committee.

5. **Permanent propane generators** were installed at dozens of major signalizations in Miami-Dade County in the late 1970's. Unfortunately, the maintenance requirements of the equipment were found to exceed the value to the public. All units were stolen, vandalized, or otherwise inoperative by 1980.

6. **Vehicle engines** can be connected to an inverter (a device for converting DC to AC current) to generate power for a traffic signal. A prototype device was demonstrated to Public Works personnel in the early 1990's. However, to the best of our knowledge, the device has never been mass-produced and would have to be re-developed. A major disadvantage is the possibility of vehicle theft.

7. **Electro-Kinetic Road Ramp Generators** can be permanently installed in the roads of the future to transfer the kinetic energy of vehicles into electrical power to drive nearby traffic signals. Such high-tech devices are being developed in England and may be ready for actual field deployment in mid 2006. Preliminary indications are that the earliest versions of these devices may have disadvantages that exceed their advantages. However, the concept is ingenious and if all the developmental bugs are worked out, the Public Works Department will be interested in arranging for a demonstration installation later in the year.

A more detailed report on the aforementioned techniques is attached if additional information is desired.

Recommendations:

In the aftermath of Hurricane Wilma, Technique Nos. 1 & 3 (portable generators and portable solar-powered signals) proved to be viable on a small scale and could be worthy of further consideration by local police departments, even though the disadvantages noted are significant and large-scale deployment would be expensive.

Technique No. 2 (permanently installed back-up battery systems) described above may be even more viable, but would only work following the County's upcoming, conversion project to LED signal heads.

Technique Nos. 4 &7 (permanent solar panels and electro-kinetic road ramp generators) are exciting future possibilities. These technologies will be studied closely as they are developed in the coming months.

As noted previously, the most promising and realistic solution to this serious problem is to require FPL to strengthen and/or relocate its existing infrastructure to where it will not be susceptible to damage by windstorms. Improving the reliability of the existing power supply system would be superior to re-inventing it and would pay off, not just in terms of reliable traffic signal operations, but a reliable power supply to all consumers.

Assistant County Manager

3/7/06
Date

Alternative Power Sources for Traffic Signals

During Power Outages

Traffic Engineering Division
Miami-Dade County Public Works Department

January 27, 2006

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1. Overview

Miami-Dade County experiences many severe storm systems from tropical storms to hurricanes. These storm systems cause major disruption to the electrical power grid system that results in traffic signal power outages which may last for days and even weeks. These traffic signal power outages result in an unsafe intersection traffic operational condition. Miami-Dade County Public Works Department (PWD) desires a solution to these frequent power outages and a resolution to the effects they are having on signalized intersections throughout the County. After intensive research and document review, several alternate power sources were found. They can be classified into four categories:

1. Battery-based Uninterruptible Power Supply System
2. Engine Electric Generator
3. Solar Power Supply and Propane Fuel Cells
4. Ramp Generator

Detailed information for these power supply systems are explained in the following sections.

2. Battery-based Uninterruptible Power Supply System

Technical Description

Battery backup systems are intended for short-term (e.g. minutes or hours) service during a power outage. The length of time they can be used depends on the number and size of the batteries in the units. The systems are often equipped with automatic switchovers to provide uninterrupted service.

Battery-based Uninterruptible Power Supply (UPS) systems can be used to power intersection traffic signals that have Light Emitting Diode (LED) signal modules in the event of a power failure. They can be permanently installed in a cabinet adjacent to the traffic signal control cabinet. The batteries are charged by the commercial electrical power supply. When the electrical power supply is interrupted, the batteries automatically begin powering the traffic signal. Their operational time ranges from about 15 minutes to 24 hours. UPS systems can respond to power outages within a fraction of a second so that the electronic equipment is not disturbed. It was found that the temperature has a significant effect on the run times provided by the UPS systems. [.1]

Many UPS systems are currently available in the United States, such as the PB 2000ITS from U.S. Traffic Corp., Novus 1000TP from Alpha Technologies, ME 1000 from TechPower Developments Inc., 24 M11 from Dimensions Unlimited Inc., Exeltech BBS from OkSolar Inc., and PowerBack UPS from Quixote Traffic Corporation, Inc. Shown below is a picture of the Exeltech BBS from OkSolar Inc., with its technical specifications.

- - 1KW true sine wave power
- - CALTRANS & TX DOT compliant
- - ANSI-C62.41 Level B2
- - Maintenance bypass switch
- - Power factor corrected charger
- - 3 state charger, temperature compensated
- - Power Transfer Switch less than 10 milliseconds, optional high speed relay (< 5ms)
- - RS-232 interface
- - Temperature range from -37 C to 74 C
- - Low battery shutdown protection

Overall system features:

- Inverter/charger designed for seamless operation together
- Certified temperature range -37C to 74C
- 3 alarm relays for external monitoring
  On battery; energized when running on battery
  Low battery; energized when 40% of battery capacity remains
  On time; energized after two hours on battery
- Low battery shutdown protection at 1.75 Volts per cell
- LED display allowing several counters and status monitoring
  BBS status: BBS mode, charge state 1, 2, or 3
  Event counter
  Event timer
  Accumulated Event time
  Battery Voltage
- Maintenance bypass switch
- Testing and certifications
  Manufactured in accordance with ISO 9000/TL 9000 quality systems
  Computerized calibration and testing of each system
  CALTRANS compliant
  TX DOT compliant
  ANSI-C62.41 Level B2
  FCC compliant to Part 15 Class A
  Totally integrated system with a 20 year MTBF

BBS charger features:

- Power factor corrected
- Standard 3 state charger; bulk, absorption, & float
- Battery temperature sensor for temperature compensated charging

BBS transfer switch features (internal or external capable):

- Transfer outside 100 or 130 VAC, restored at 105 and 125 VAC (all +/- 2VAC)
- Optional power conditioning within acceptable utility range
- Several relay transfer time options available
  Less than 5 milliseconds (internal)
  Less than 20 milliseconds (internal)
  Less than 50 milliseconds (external)

RS-232 interface allows battery parameter changes:

- Easily change parameters to fit different battery requirements
- Battery minimum and maximum voltage per cell
- Float voltage adjustments
- Modify temperature compensation rate
- 3 state charging or (float mode only) selectable

Cost

The cost of UPS battery backup systems varies widely depending on the size of the unit and the operational time. For example, the cost to install a UPS system that provides 20 hours of backup power is about $25,000 and the annual maintenance cost is about $700 per intersection. Therefore, installing a UPS system at 1,500 major intersections will cost approximately $37.5 million and their maintenance will cost $1 million per year.

Implementation Considerations

Some battery backup systems use batteries that contain hazardous materials (e.g., acid, lead, cadmium). These systems must be installed in a controlled environment. They must also be disposed of following strict environmental requirements.

3. Engine Electric Generators

Many cities have used different types of engine electric generators to power traffic signals. These generators can be either permanent or portable at intersections. Both types of generators have been used in Miami-Dade County since 1970.

3.1. Permanent On-site Backup Generation

Technical Description

Standby permanent on-site backup generator consists of an electric generator that is driven by an engine. Reciprocating engines are currently the most commonly used type of standby on-site generator. Diesel oil is the most common fuel source. A number of new units that use turbine engines are now commercially available. These units are powered by various grades of oil, natural gas or propane.

Standby permanent on-site backup generators are designed for intermittent use and are not recommended for continuous, long-term operation. Using such generators for approximately 1,000 hours per year would approach the design limits for some units. Disconnecting service cables and installing jumper cables to power an intersection with a generator is time-consuming and exposes technicians to electrical hazards. A connection is usually built into each signal cabinet and this eliminates the need for the technician to disconnect and connect the unit. When the generator is started, it powers the relay in the signal cabinet and powers the intersection. When the generator is disconnected, the relay falls out and switches back to the traffic signal's normal power.

The equipment comes in a wide range of sizes from 1 to 10,000 kW. Units can be grouped to provide larger quantities of power. Output voltage from the smaller units is generally 110 volts, while the larger units can produce power up to 600 volts or higher.

Cost

In general, diesel-powered standby generators are less expensive to operate than natural-gas-powered generators. Depending on the price of natural gas, gas units might have lower overall costs. Diesel electric generators are recommended due to their longevity and lower operating costs. Today's modern diesel generators are quiet and normally require much less maintenance than comparably sized gas (natural gas or propane) electric generators. Fuel costs per kW produced with diesels are normally 30 to 40 percent less than gas units. The fuel consumption for the diesel generator is 10 kWH per gallon.

Implementation Considerations

Standby permanent on-site backup generators can be equipped with either manual or automatic start-up controls. The manual controls are simpler and lower in cost, but a qualified technician must be available to start the unit when the utility power fails.

On-site fuel storage is an issue that must be considered when selecting standby generator equipment. Gasoline is generally avoided as a fuel for standby generators because it is necessary to store a large quantity of this highly volatile energy source on site. Diesel fuel is less volatile and can be more readily stored in sufficient quantity. Natural-gas-fired units frequently are exempted from the on-site fuel storage requirement, although some facilities rely on on-site propane storage as a backup in case the gas supply is disrupted at the same time as the electrical supply.

Environmental issues can influence the choice of standby generator equipment. Air pollutant emissions and engine noise are the primary environmental concerns. In some applications, the use of diesel engines might be prohibited because of air pollutant emission requirements.

3.2. Portable/Temporary Generation

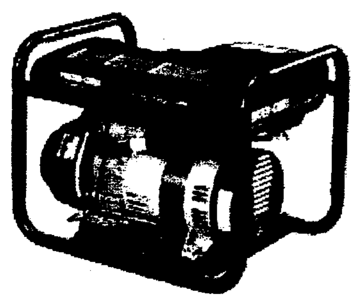
Technical Description

Portable generation systems are engine generator sets mounted on a truck or trailer, which allows them to be moved into position either in anticipation of a power outage or after the occurrence of a power outage.

Portable generation units generally range in size from 5 to 5,000 kW and can be connected together to provide larger blocks of power. Most are diesel-powered, but some of the newer units utilize turbine engines.[2] Some manufacturers provide portable generator units for rental but they may also be purchased.

An example of a portable electric generator (Porter-Cable PCCTE 300) is shown below.

- 3,000 rated watts, 3,750 surge watts
- 4 gallon tank provides 11.5 hours of run time at half load and 7.2 hours of run time at full load between fills
- 120 VAC duplex outlet
- Tecumseh 6 HP Enduro engine with: overhead valves, cast iron sleeve, and low oil protection
- Advanced alternator design
- 4 gallon tank capacity
- 69.5 dBA noise level
- Dimension: 24" length, 20" width, and 19" height
- Weight: 102 lbs



Cost

On the basis of cost per kilowatt of power, portable generators tend to be more expensive than fixed, on-site standby generators. [3]The cost for a 3,000 watt generator, which is required by Florida Department of Transportation, is around $1,000.

Implementation Considerations

To use a portable generation unit, appropriate connections and switching equipment must be installed at the intersections. A cabinet that expects to use portable generation equipment on a regular basis should have the connection equipment designed and permanently installed to allow for rapid hook-up. Prior to storage or shipment of portable generators, all gasoline must be drained from the fuel tanks. Noise and air pollutant emissions from engines are environmental concerns associated with portable generators. Portable generators can also be stolen and they often ran out of fuel before they could be refilled.

The size of generators could be minimized by replacing incandescent signal lights with the newer LED signal lights. The LED signal units require less power consumption. Portable generators require refueling every 6 to 8 hours. This would be a challenge, particularly with gasoline shortages that would be experienced in a storm event. The potential to lose track of portable generators is high as they are not fixed.

4. Solar Power Supply and Propane Fuel Cells

Pollution-free electricity generation technology is expected to compete with traditional methods of creating and distributing electricity. Engines that use photovoltaic (solar energy), propane fuel cells and other advanced technologies are being developed. Among those, solar power is being considered as a primary energy source to empower devices at both urban and rural areas by many State DOTs.

4.1. Solar Power Supply

Using solar energy for power has been a concept for over a hundred years. Advances in technology have allowed solar energy to become less expensive and more appropriate for commercial use. Solar energy can be broadly classified in two categories on the basis of its use – Solar Active (Direct Use) and Solar Passive (Indirect Use). Solar Active can be divided into two forms – Solar Thermal (Heating Application) and Solar Photovoltaic (Electricity Generation). Solar Photovoltaic (PV) systems generate electric power for traffic signals.

Solar panels are utilized in either a permanent condition or a portable condition. To date permanent solar panel technology has not been used to power a full traffic signal. Most solar panels are portable or temporary. In this research, only temporary solar powered traffic signals are considered.

Technical Description

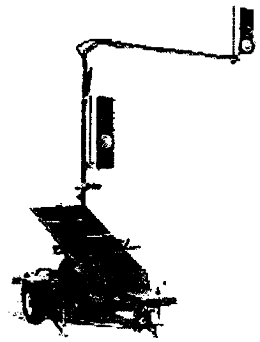
Solar Photovoltaic Technology is employed for directly converting solar energy to electrical energy by the using "solar silicon cell." The electricity generated can be utilized for different applications directly or through a battery storage system. The energy generated and stored in batteries can then power electronic devices. Portable solar traffic systems provide solar powered traffic controls to cities across the United States. It is a viable low-cost alternative to expensive hardwired installation. The scope of traffic applications has broadened from traffic counters to flashing beacons, to portable traffic signals. Below is an example picture and general technical specifications for a solar powered LED traffic signal (TTLS - 612) from a Canadian company – Ver - Mac.

Features:

- System comes standard with two 12" LED signals heads on each trailer
- Synchronization is maintained through radio communications

- Primary and secondary trailers may be positioned up to 1 mile apart

Structure:



- Overall length: 174"
- Overall width: 86"
- Extended height: 190"
- Traveling height: 90"
- Weight: 3500 lb.
- Coupler: 2" coupler
- Brake actuator: 7500 lb

Programming:

- 3 traffic flow settings (light, moderate, and heavy)
- Automatic mode: the user enters the distance between the heads, the approximate number of vehicles flowing through the zone, and the posted speed limit; the controller then automatically calculates the timing of the lights
- 18 pre-defined settings: offers the user factory preset timings
- 12 user-defined settings: allows the user to adjust timing to meet their specific needs
- Time split scheduling: allows the user to program the system to have several timing schedules at different times of the day, therefore taking into account differences in traffic flow at different times of the day
- Software allows the user to download a status log from the controller to a laptop

Solar Power Supply:

- Various configurations of solar panels and batteries are available
- Standard is: sixteen 6-volt batteries
- 300-watt solar array
- Solar regulator with battery surcharge protection
- Solar panels tilt and rotate independently of the trailer

Options:

- Vehicle detection
- Countdown display
- Data-log program
- Third signal head
- Battery charger
- AC connection
- Cell phone warning system
- Power
- Additional trailers may be added for 3- and 4-way traffic control
- GPS synchronization

- Directional antennas for over 1 mile

The table below shows another example of solar powered LED traffic signals manufactured by an India company – Gujarat Energy Development Agency:

SOLAR POWERED LED TRAFFIC SIGNALS	
System Operation	
Operation	14 hours operation and 10 hours blinking per day
Auto / Manual	Fully automatic operation with facility for manual operation
Power Source	Hybrid Power source, integrating Solar and Grid Power, with auto change-over from Solar to Grid and vice-versa
Source preference	First preference to Solar
Percentage of Power Sharing	50% Solar and 50% Grid
Back-up	In case of failure of both Solar and Grid Power source, System can operate for 10 hrs form a fully charged battery.
Configuration	Two sets of Signal-heads per road One set of Pedestrian signals per road One count-down timer per road
System Controller	
System voltage	24 V DC
Controller	PLC / Microcontroller
Networking	Compatible for GPS/ GSM! RS 422 interface
Programmability	Programmable Timing with on-site modification
Operating hours	14 hours operation and 10 hours blinking per day
Future Upgrades	Capability for Synchronization, remote monitoring & control
System Up-time	Greater than 98%
Signals	
LED Array	Ultra bright, suitable for daylight viewing
LED design life-cycle	10 Years
Enclosures / Housing	NEMA 12, IP – 66 Standards
Pole structure	Mild Steel with vapocure finish (Viola Blue)
Visibility	500 meters and above
Signal Head	Modular with Tilt and Rotate feature
Count Down Timers	Timer for residual time for green signal
Pedestrian / Free left signals	Composite Red / Green LED signal
Solar Array Capacity	444 Wp (min)
Solar Charge Controller	24 Volts / 15 Amps
Battery Bank	

Type	Sealed Maintenance Free, Lead Acid
Capacity	80 Ah
Terminal voltage	24 V DC
Max. depth of discharge	80 %
Grid power	
Grid Input	230 V AC / 50 Hz / Single Phase
Grid Changer	24 V / 10 Amps

Cost

The cost of the Canadian TTLS-612 solar-powered traffic signal is between $45,000 to $50,000. A lower cost solar-powered traffic signal is available from IST International Ltd. in Ohio. The total cost of the IST system is about $11,000 per intersection. Detailed information for this product is in Appendix A.

Implementation Considerations

Recently, seven solar-powered traffic signals with battery storage were successfully utilized by the City of Coral Springs after the recent hurricanes. There are no noise and air pollutant emissions from the solar PV system. The system is trailer mounted with the signal lights placed in the intersection; therefore, the devices stand relatively unprotected. Occasionally, they get hit and destroyed by errant vehicles. Deploying, maintaining, removing and storing hundreds or thousands of portable traffic signals to serve 1,500 intersections in Miami-Dade County would be a massive undertaking.

4.2. Propane Fuel Cells

Propane fuel cells are being explored to complement or replace solar-power, especially by states that suffer through long winters and harsh environment. This concept has already been used in vehicle design.

Technical Description

Functioning similar to a battery, which uses electrochemical conversion, fuel cells take in hydrogen-rich fuel and oxygen and turn them into electricity and heat. The waste product is water. The hydrogen can be derived from gasoline, natural gas, propane or methanol. The hydrogen, which comes into the anode side of the fuel cell, is converted into electrons and hydrogen ions. The electrons are repelled by the anode and flow to the cathode. The cathode accepts the electrons as well as oxygen, which combine with the hydrogen ions from the anode, and converts them into water.[4]

Cost

The propane generator engine consumes 0.37 pounds of propane per hour at 500 watts. The propane generator is expected to cost $570 for six months[.5].

Implementation Considerations

The hydrogen tanks need to be changed on a regular basis, increasing the operating costs. The Washington DOT is using propane fuel cells as an alternative power source. Alaska DOT has considered a propane generator using fuel cell technology. The Texas DOT is developing, testing and installing a prototype residential power system that runs on a propane fuel cell.

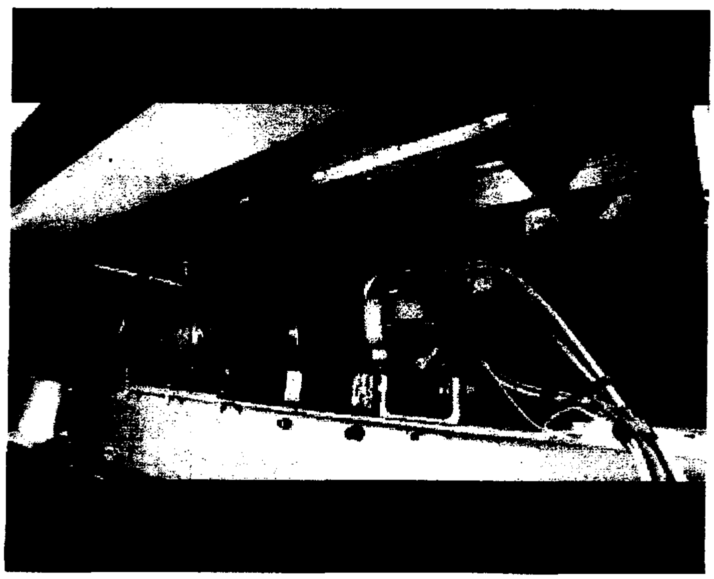
5. Ramp Generator

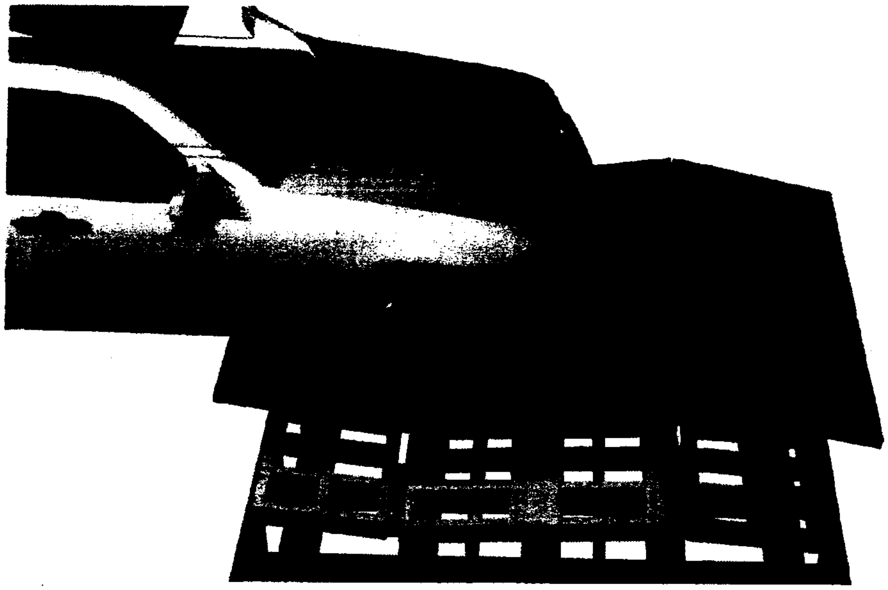
British inventor Peter Hughes has developed a generator which is powered by the pressure of vehicles passing over it. The ramp generator produces electricity from the energy of vehicles passing over the ramp and storing the electricity in a battery. The concept of a ramp generator has been in the developing stages by Mr. Hughes over the past 12 years and is now ready to come to the market. Over 200 local authorities in the UK have expressed interest in attaining the ramps to power their traffic lights and other road signs. The first production-line models will be installed in car parks in the middle of 2006.

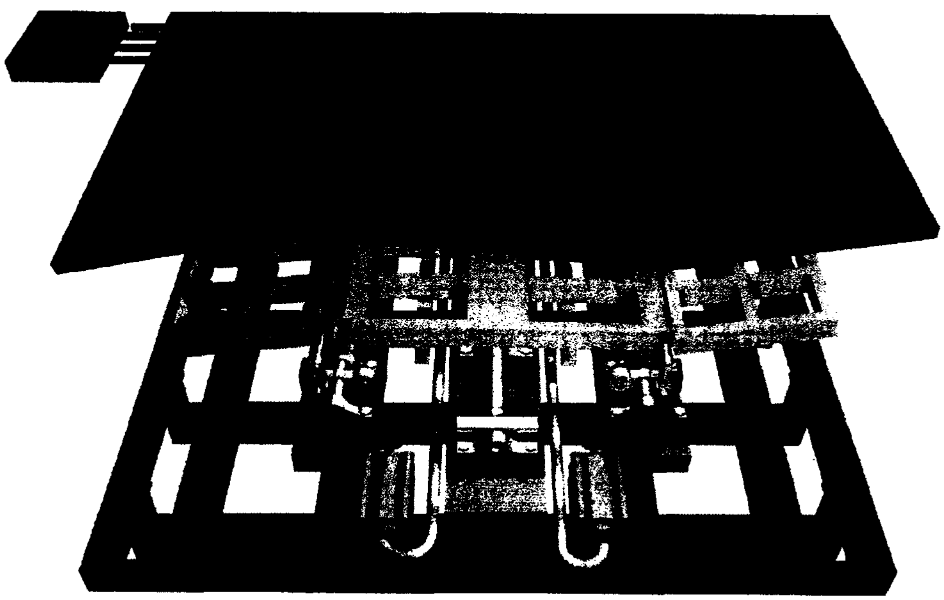
Technical Description

The ramp operates by virtue of a number of articulated plates placed in the road. When a vehicle passes over the ramp, its weight is exerted on the plates, the plates move up and down and by means of a specially designed and developed mechanism, a generator is driven, which is capable of producing AC current or DC current. The generator's output will vary according to the frequency and weight of the traffic, but in general terms it will be capable of producing between 5 and 10 [r6]kW.

The ramp is designed to be situated in parts of the roadway where vehicles have to slow down; for example, on downhill gradients, when approaching traffic lights or roundabouts as well as traditional traffic calming areas. When a vehicle passes over the ramp, the ramp by means of kinetic energy produces electricity. The slight extra resistance of a vehicle passing over the ramp makes no difference to the vehicle's fuel consumption. A detailed ramp operation is shown in the following pictures.

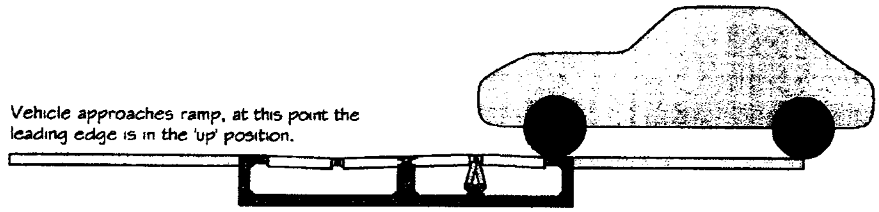




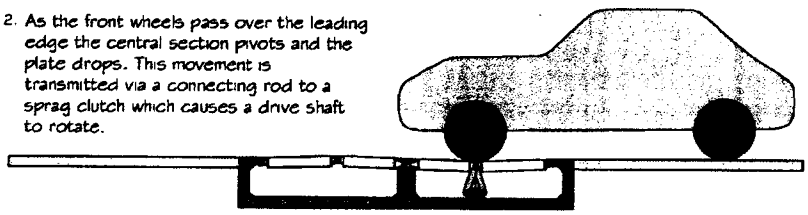


RAMP OPERATION

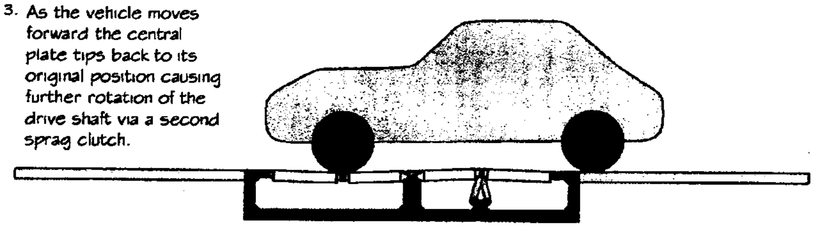
1. Vehicle approaches ramp, at this point the leading edge is in the 'up' position.

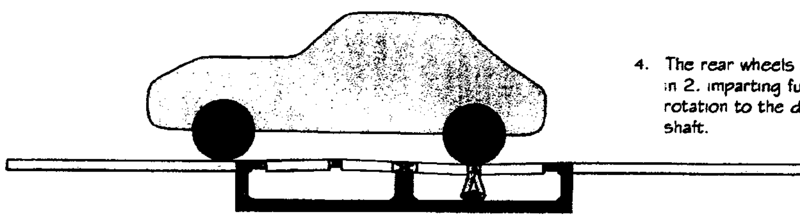


2. As the front wheels pass over the leading edge the central section pivots and the plate drops. This movement is transmitted via a connecting rod to a sprag clutch which causes a drive shaft to rotate.

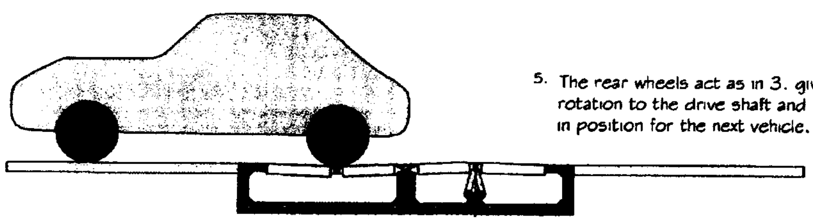


3. As the vehicle moves forward the central plate tips back to its original position causing further rotation of the drive shaft via a second sprag clutch.





4. The rear wheels act as in 2. imparting further rotation to the drive shaft.



5. The rear wheels act as in 3. giving a final rotation to the drive shaft and leaving the ramp in position for the next vehicle.

HUGHES RESEARCH

Cost

The cost of a ramp generator ranges approximately from $17,500 to $40,000 per unit plus shipping costs, which would vary between $1,000 and $5,000.

Implementation Considerations

The ramp is unobtrusive, silent in operation, causes no discomfort to the vehicles occupants and is entirely safe in operation. The ramp is designed to require minimal maintenance. The mechanism is comparatively simple. The bearings, for example, are self lubricating and sealed for life. Other mechanisms are also designed to operate for long periods without maintenance. If maintenance is required, the whole assembly would be removed from the road to be overhauled off site and a replacement ramp fitted. This maintenance removal operation typically takes half an hour, thereby resulting in minimal disruption to traffic.

The ramp will operate in relatively hostile conditions, for example, even if the road was flooded to a depth that would allow normal traffic to utilize it. The ramp is designed to last between 5 - 7 years depending upon the level of traffic flow. It has the capability to store electricity by means of a storage battery facility. The batteries can be charged utilizing the excess energy generated during periods of heavy traffic.

6. Summary

In order to compare different types of traffic signal power sources, below is a comparison table.

Signal Power Sources	**Supplier**	**Initial Cost per Intersection**	**Annual Maintenance Cost per Intersection**
2. Battery-Based UPS		$25,000 (20 hours)	$700
3.1 Electric Generator (Permanent)		$6,000	$1,200
3.2 Electric Generator (Temporary)	Porter-Cable Inc.	$1,000	$200
4.1 Solar Power System	IST International Ltd. Ver-Mac Inc	$11,000 $45,000 - $50,000	Mobilization Cost
5. Ramp Generator	Hughes Research Ltd.	$35,000 - $80,000	Minimal

In conclusion, every power source has its own advantages and disadvantages. At this time, the most viable options appear to be: (1) battery-based UPS plus an electric generator and (2) solar-powered traffic signals. Between these two devices, alternative 1 maybe use for those locations where the traffic signal heads remains intact. However, for intersections that lose their signal heads during hurricanes, solar-powered traffic signals may be used to direct traffic.

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Appendix A

Portable Solar-Powered Traffic Signals